

Allegheny Mountain Dusky Salamander
Photo: Rob Tervo



Northern Dusky Salamander
Photo: Rob Tervo



Allegheny Mountain Dusky Salamander (*Desmognathus ochrophaeus*)

and Northern Dusky Salamander (*Desmognathus fuscus*) in Ontario

Ontario Recovery Strategy Series

Recovery strategy prepared under the *Endangered Species Act, 2007*

Natural. Valued. Protected.

About the Ontario Recovery Strategy Series

This series presents the collection of recovery strategies that are prepared or adopted as advice to the Province of Ontario on the recommended approach to recover species at risk. The Province ensures the preparation of recovery strategies to meet its commitments to recover species at risk under the Endangered Species Act (ESA) and the Accord for the Protection of Species at Risk in Canada.

What is recovery?

Recovery of species at risk is the process by which the decline of an endangered, threatened, or extirpated species is arrested or reversed, and threats are removed or reduced to improve the likelihood of a species' persistence in the wild.

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Under the ESA a recovery strategy provides the best available scientific knowledge on what is required to achieve recovery of a species. A recovery strategy outlines the habitat needs and the threats to the survival and recovery of the species. It also makes recommendations on the objectives for protection and recovery, the approaches to achieve those objectives, and the area that should be considered in the development of a habitat regulation. Sections 11 to 15 of the ESA outline the required content and timelines for developing recovery strategies published in this series.

Recovery strategies are required to be prepared for endangered and threatened species within one or two years respectively of the species being added to the Species at Risk in Ontario list. There is a transition period of five years (until June 30, 2013) to develop recovery strategies for those species listed as endangered or threatened in the schedules of the ESA. Recovery strategies are required to be prepared for extirpated species only if reintroduction is considered feasible.

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For more information

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DECLARATION

The recovery strategy for the Allegheny Mountain Dusky Salamander and the Northern Dusky Salamander was developed in accordance with the requirements of the *Endangered Species Act, 2007* (ESA). This recovery strategy has been prepared as advice to the Government of Ontario, other responsible jurisdictions and the many different constituencies that may be involved in recovering the species.

The recovery strategy does not necessarily represent the views of all of the individuals who provided advice or contributed to its preparation, or the official positions of the organizations with which the individuals are associated.

The goals, objectives and recovery approaches identified in the strategy are based on the best available knowledge and are subject to revision as new information becomes available. Implementation of this strategy is subject to appropriations, priorities and budgetary constraints of the participating jurisdictions and organizations.

Success in the recovery of this species depends on the commitment and cooperation of many different constituencies that will be involved in implementing the directions set out in this strategy.

RESPONSIBLE JURISDICTIONS

Ontario Ministry of Natural Resources
Environment Canada – Canadian Wildlife Service, Ontario

EXECUTIVE SUMMARY

Both the Allegheny Mountain Dusky Salamander (*Desmognathus ochrophaeus*) and the Northern Dusky Salamander (*Desmognathus fuscus*) are listed as endangered in Ontario under the *Endangered Species Act, 2007*. The Allegheny Mountain Dusky Salamander is a federally endangered species listed on Schedule 1 of the *Species at Risk Act*. The Northern Dusky Salamander in Ontario is yet to be assessed at the federal level.

Like all plethodontid salamanders, these species are lungless and rely on their moist skin for respiration. They are thus restricted to moist environments and avoid conditions that risk their dehydration. Both species are typically found along the edges of small woodland streams and in damp seepage areas where there is an abundance of logs, stones and leaf litter.

Dusky salamanders have a characteristic light line that runs from the corner of the mouth to the eye. The two species can best be distinguished from each other by the cross-sectional shape of the tail, the colour of the dorsal stripe and the colour of the underside. The Allegheny Mountain Dusky Salamander has a tail that is rounded in cross-section, an evident yellow- to red-coloured dorsal stripe with chevron shaped darker patches running along it, and a typically dark brown or black underside. The Northern Dusky Salamander has a keeled tail that is laterally compressed and triangular in cross-section, a uniformly tan or brown dorsal stripe, and a cream-coloured underside.

The principle limiting factor for the Allegheny Mountain Dusky Salamander and the Northern Dusky Salamander in Ontario is their extremely restricted range. In Ontario, Allegheny Mountain Dusky Salamanders have now been identified from two localities in the Niagara Gorge, while Northern Dusky Salamanders are known only from a single site. As both species occupy very similar habitats, and share many characteristics, the threats to their survival and recovery are virtually identical. The current habitat is so limited that any degradation is likely to compromise the long-term survival of these salamanders in Ontario.

The Allegheny Mountain Dusky Salamander and Northern Dusky Salamander in Ontario utterly depend upon the groundwater discharge that feeds the streams and seeps in which they dwell. Any decrease, curtailment or interruption of the groundwater is considered a serious threat to the continuing existence of these salamanders. Landslides or mudslides in the Niagara Gorge that in any way affect the salamanders' streams and stream-side habitats pose severe threats. Further, degradation of habitat may occur when hikers venture off the maintained trail and inadvertently stir up the stream bed, trample vegetation and increase erosion. Clearing of the habitats used by these salamanders would also constitute a serious threat.

The recovery goal is to safeguard the existing known populations of Allegheny Mountain Dusky and Northern Dusky Salamander species, and if feasible, introduce each species

to unoccupied habitat within the Niagara Gorge that is either created or found to be suitable, with the aim of increasing known population sizes by 50 percent. The four recovery objectives are to:

- protect and enhance existing significant habitat for Allegheny Mountain Dusky Salamanders and Northern Dusky Salamanders in Ontario;
- conduct a thorough population study, and if necessary maintain the genetic health of Allegheny Mountain Dusky Salamander and Northern Dusky Salamander populations in Ontario;
- locate additional populations, and expand the current ranges of Allegheny Mountain Dusky Salamanders and Northern Dusky Salamanders through introductions where appropriate; and
- elicit public support and collaboration in the protection and recovery of Allegheny Mountain Dusky Salamanders and Northern Dusky Salamanders in Ontario.

The areas to be considered for habitat regulation include the streams and seeps inhabited by the salamanders, plus the surrounding forested habitat up to 75 m away from the edges of seeps and streams. In addition, the area between the two Allegheny Mountain Dusky Salamander populations should be protected as a dispersal corridor. Also to be considered are the catchment basins supplying the groundwater that feeds the springs from which the streams and seeps originate.

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1.0 BACKGROUND INFORMATION

1.1 Species Assessment and Classification

COMMON NAME: Allegheny Mountain Dusky Salamander

SCIENTIFIC NAME: *Desmognathus ochrophaeus*

SARO List Classification: Endangered

SARO List History: Endangered (2008)

COSEWIC Assessment History:

Allegheny Mountain Dusky Salamander (Carolinian population) – Endangered (2007)

Allegheny Mountain Dusky Salamander – Threatened (2001), Special Concern (1998)

SARA Schedule 1: Endangered (March 5, 2009)

RANKINGS: GRANK: G5 NRANK: N2 SRANK: S1

COMMON NAME: Northern Dusky Salamander

SCIENTIFIC NAME: *Desmognathus fuscus*

SARO List Classification: Endangered

SARO List History: Endangered (2004)

COSEWIC Assessment History: Endangered (2012), Not at Risk (1999)

SARA Schedule 1: No Schedule, No Status

RANKINGS: GRANK: G5 NRANK: N3N4 SRANK: S1

The glossary provides definitions for technical terms, including the abbreviations above.

1.2 Species Description and Biology

Species Descriptions

Dusky salamanders have a characteristic light line that runs from the corner of the mouth to the eye. The hind legs are substantially larger than the front legs (Petranka 1998). These features serve to distinguish both species from any other salamanders that may be present in the Niagara Gorge.

The Allegheny Mountain Dusky Salamander ranges in size from 70 to 110 mm total length, with males roughly six to twenty percent longer than females (Bruce 1993, Orr 1989, Pauly and Watson 2005). Northern Dusky Salamanders range from 60 to 140 mm total length, with males about seven percent larger than females (Means 2005). Colour and pattern are variable in each species, although the Allegheny Mountain Dusky Salamander is typically more brightly coloured, and the Northern Dusky Salamander usually has black specks or spots present along the sides. Allegheny Mountain Dusky Salamander larvae are 13 to 18 mm long and have dark dorsolateral stripes, often with spots (Petranka 1998). Northern Dusky Salamander larvae are 12 to 20 mm total length with paired blotches or spots along the back. Both species have 14 costal grooves.

The two species can best be told apart by the colour of the dorsal stripe, the cross-sectional shape of the tail and the colour of the underside (Tilley 1969, Petranka 1998). The Allegheny Mountain Dusky Salamander has a tail that is rounded in cross-section, an obvious yellow to red-coloured dorsal stripe with chevron shaped darker patches running along it and a typically dark brown or black underside. In contrast the Northern Dusky Salamander has a keeled tail that is laterally compressed and triangular in cross-section, a uniformly tan or brown dorsal stripe and a cream-coloured underside.

Species Biology

Like all plethodontid salamanders, these species are lungless and rely on their moist skin for respiration. They are thus restricted to moist environments and avoid conditions that risk their dehydration (Spotila 1972, Alvo and Bonin 2003). Dry conditions restrict activity and the animals' low metabolic rates, large energy stores, and resistance to starvation enable them to survive extended periods of time without food (Feder 1983, Feder and Londos 1984).

Both species are typically found along the edge of small woodland streams and in damp seepage areas where there is an abundance of logs, stones and leaf litter (Means 2005, Pauly and Watson 2005). They are nocturnal and remain under cover objects at the edges of streams and seeps during the day. Peak surface activity occurs an hour after sunset on warm, wet nights (Keen 1979, Holomuzki 1980). Adults and juveniles likely move short distances along stream channels where there is continual moisture. However, the Mountain Dusky Salamander is more terrestrial than the Northern Dusky Salamander and is known to venture 75 m away from streams (Organ 1961).

In the northern part of their ranges including New York (and likely Ontario), Allegheny Mountain Dusky and Northern Dusky Salamanders mate during both autumn and spring (Bishop 1941, Petranka 1998). Courtship is lengthy and intricate, involving a spermatophore laid by the male that the female picks up for internal fertilization of the eggs. Grape-like egg clusters are attached to the undersides of logs or rocks, or deposited amid moss, clumps of leaf litter or organic debris, usually within a meter of a stream or seep (Bishop 1941, Krzysik 1980, Hom 1987). The Allegheny Mountain Dusky Salamander lays clutches of one to two dozen eggs; the Northern Dusky Salamander lays clutches of two to three dozen eggs (Hall 1977, Petranka 1998, Means 2005, Pauly and Watson 2005). Females guard their eggs for the duration of the incubation period (Houck et al. 1985, Forester 1979). Eggs hatch in 6 to 10 weeks (Bishop 1941). Eggs laid in early spring hatch in early fall; eggs laid in the fall hatch the following spring (Bishop 1941, Keen and Orr 1980, Orr 1989).

Larvae inhabit slow moving streams and seeps, and shelter underneath rocks or other debris. Allegheny Mountain Dusky Salamander larvae may metamorphose into adult form in as little as a few weeks or may take up to eight months (Keen and Orr 1980). Northern Dusky Salamanders will remain larvae for eight months to a year (Means 2005). Sexual maturity in Allegheny Mountain Dusky Salamanders is attained when they are about three years old (Hall 1977) and in Northern Dusky Salamanders at two years (Bishop 1941).

Adults and larvae of both species feed upon aquatic and terrestrial insects such as spiders, beetles, earthworms, snails, mites, aphids and insect larvae (Fitzpatrick 1973, Keen 1979, Petranka 1998). All life stages of dusky salamanders are preyed upon, principally by snakes, crayfish, aquatic insects, small mammals and birds (Bishop 1941, Hom 1988, Orr 1989, Whiteman and Wissinger 1991, Petranka 1998). Northern Dusky Salamanders are also known to prey upon smaller salamanders (Means 2005).

1.3 Distribution, Abundance and Population Trends

Allegheny Mountain Dusky Salamanders extend from eastern Tennessee through the Appalachian Mountains and along the southern shores of Lake Erie and Lake Ontario to extreme southern Quebec. Northern Dusky Salamanders follow a similar, yet wider, distribution and range from South Carolina through much of the Northeast United States into southern Quebec. In Ontario, Allegheny Mountain Dusky Salamanders are now known to occur at two localities in the Niagara Gorge, while Northern Dusky Salamanders are known only from a single population. All sites are located along the Niagara River, downstream from Niagara Falls, near Queenston (Figure 1). The closest Allegheny Mountain Dusky Salamander and Northern Dusky Salamander populations are separated by approximately four kilometres of Niagara River shoreline.

Dusky salamanders were first reported from Ontario in 1908 (Nash 1908), although a general area was not mentioned until Bishop (1941, 1943) reported dusky salamanders occurring in "Ontario opposite Buffalo, New York". In 1989, dusky salamanders were

discovered in two localities in the Niagara Gorge: the first locality was a stream in the Whirlpool area and the second was a stream just south of Queenston (Kamstra 1991). These sites were the first specific localities identified for dusky salamanders in Ontario and one specimen from each locality was collected for museum records (Kamstra 1991). Originally specimens from both localities were identified as Northern Dusky Salamanders. However, in 2004, local MNR staff suspected that the Queenston dusky salamanders were actually Allegheny Mountain Dusky Salamanders based on physical appearance. Genetic analysis confirmed the salamander population to be Allegheny Mountain Dusky (Markle and Green 2005, 2006, Markle et al. 2006).

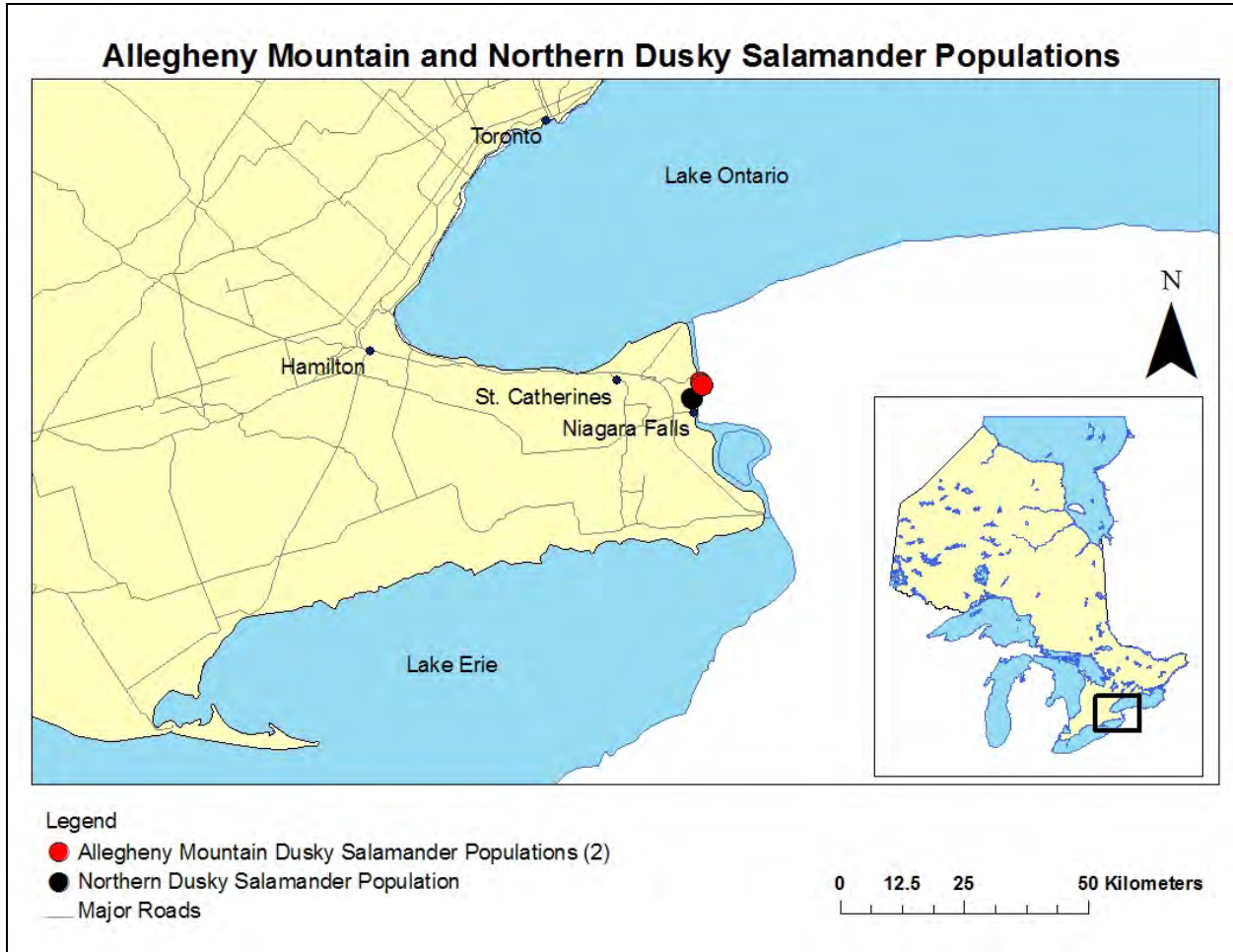


Figure 1. Distributions of Allegheny Mountain Dusky Salamanders and Northern Dusky Salamanders in Ontario. (Note that the Allegheny Mountain Dusky Salamander populations are represented by two closely overlapping circles on the map.)

In the fall of 2010, partnership between staff of Ontario Power Generation (OPG), along with the Ontario Ministry of Natural Resources' Niagara Area office, led to the discovery of a second site for Allegheny Mountain Dusky Salamanders in the Niagara Gorge (Weller 2010, 2011) bringing the total to two known populations of Allegheny Mountain

Dusky Salamanders in Ontario. The two populations are found half a kilometre apart southeast of the town of Queenston.

The single population of Northern Dusky Salamanders inhabits a steep bank in the vicinity of the Whirlpool, and is watered by eight or nine seeps that flow into the Niagara River. Surveys along the escarpment have failed to uncover any additional populations of Northern Dusky Salamanders, and the nearest known population is over 30 km away in New York State (Bonin 1999, Markle and Green 2005).

While there are no precise data on abundance or trends for either species in Ontario, as of 2012, 38 Allegheny Mountain Dusky Salamanders have been observed in the Queenston population (COSEWIC 2007, A. R. Yagi, pers. comm. 2012, W. F. Weller, pers. comm. 2012) and a total of 17 individuals have been observed from the Smeaton Creek population (Weller 2010, 2011, W. F. Weller, pers. comm. 2012). For Northern Dusky Salamanders, a total of 79 individuals have been observed in the Whirlpool site since 2005 (A. R. Yagi, pers. comm. 2012). For both species, and in each population, three age-classes (including larvae, juveniles, and adults) have been found, along with eggs. Based on the information to date, it appears that all three populations are viable and self-sustaining.

1.4 Habitat Needs

Terrestrial Habitat

Throughout their ranges, Allegheny Mountain Dusky and Northern Dusky Salamanders occur in a variety of aquatic or semiaquatic forested habitat, and are often found to be abundant in or about seeps, as well as along the margins of small streams (Petranka 1998, Means 2005, Pauly and Watson 2005). The forest canopy is critical in maintaining shady conditions, which protects against high temperatures and maintains humidity. Leaf litter, woody debris, rocks and naturally vegetated habitat between and adjacent to individual seeps and small streams are important for dispersal for both species. Cover objects such as logs, leaf litter, moss and rocks in these areas provide shelter and protection from predators and inclement weather. Adults of both species will actively defend space under cover objects from other salamanders (Petranka 1998). Dusky salamanders are nocturnal and remain under cover objects during the day, coming out at night to forage along seepage areas and streams, and across the forest floor. Adult salamanders of both species feed predominantly on terrestrial or semi-terrestrial invertebrates (Petranka 1998).

Moist retreats also offer the ideal habitat to lay eggs, and nests are often found under rocks in seepage banks, or in mud crevices beneath logs or moss (Jones 1986, Petranka 1998). Females of both species are known to remain with their eggs to defend them and will greatly reduce foraging during this time (Fitzpatrick 1973, Montague and Poiniski 1978).

The average home range for an Allegheny Mountain Dusky Salamander is likely less than one square metre (Petranka 1998). Some individuals in the United States, however, are known to venture up to 75 m from water (Organ 1961), and during optimal conditions may venture much further. Allegheny Mountain Dusky Salamanders in general are found to be more terrestrial than Northern Dusky Salamanders and are often found some distance from permanent seeps or streams (Organ 1961). For Northern Dusky Salamanders, home ranges are estimated to remain within 15 m of a stream, with a maximum home range recorded at 114 m² (Hom 1987, Petranka 1998). However, during cool and wet periods dusky salamanders can likely travel large distances between seepage areas.

Aquatic Habitat

Once larvae emerge from eggs they live in seepages, sluggish portions of streams, or in wet cavities along the stream edge until they transform into adults (Petranka 1998). During this time they feed on small invertebrates. Seasonal factors such as moisture, levels of seeps and time of year that the eggs are laid may influence the length of the larval period and whether or not they overwinter as larvae.

Winter Retreats

These salamanders are active on the ground surface at all times of year except during the coldest winter months. During the colder months, salamanders overwinter in subsurface cavities, burrows, fissures and seepages, to depths of 90 cm or more, where they can avoid freezing temperatures and remain moist (Bishop 1941, Organ 1961). Often adults and juveniles are found to congregate together in these retreats (Petranka 1998). Northern Dusky salamanders are found to move 12 to 25 cm below ground when temperatures drop below 7°C (Ashton 1975).

Indirect Habitat

As both species require access to cool, highly oxygenated, first-order forested streams or seeps, they are thus highly dependent upon specific hydrological conditions that ensure a constant supply of groundwater to the source springs. As a result, indirect habitat includes the source water of streams and seeps that is so critical to their survival.

1.5 Limiting Factors

The principle limiting factor for Allegheny Mountain Dusky Salamanders and Northern Dusky Salamanders in Ontario is their extremely limited range. Each species is known only from one or two localities of very limited extent. They are constrained to these sites by highly specific requirements for a stream habitat that is rare within southern Ontario. The limited distribution of suitable sites in the Niagara region restricts the salamanders to the Niagara Gorge and curtails their capability for dispersal (Oldham 2006). There is no possibility for a rescue effect via immigration from populations in New York because none are nearby and the Niagara River is an effective barrier to dispersal.

Nevertheless, because the Ontario populations of Allegheny Mountain Dusky Salamanders and Northern Dusky Salamanders are isolated from each other by inhospitable terrain, it is unlikely that hybridization or competition between the species will occur, such as has been documented where they co-occur on Covey Hill in Quebec (Sharbel et al. 1995, Boutin 2006). However, hybridization and competition between the species is likely to occur if the species are transplanted to, or invade, each other's habitats. The larger, more aggressive Northern Dusky Salamander is an important competitor of Allegheny Mountain Dusky Salamanders where the species are found to occur together. Northern Dusky Salamanders are found to be capable of driving Allegheny Mountain Dusky Salamanders away from preferred habitat closer to the streamside (Krzysik 1979, Grover and Wilbur 2002, Boutin 2006). Thus, in the presence of Northern Dusky Salamanders, Allegheny Mountain Dusky Salamanders preferentially occupy drier microhabitats on finer substrates farther from the water's edge (Tilley 1997, Petranka and Smith 2005, Boutin 2006). At the same time, because Allegheny Mountain Dusky Salamanders have higher tolerances for a wider range of ecological conditions than do Northern Dusky Salamanders (Tilley 1970, Grover 2000), they are able to survive well in such habitats.

1.6 Threats to Survival and Recovery

As both the Allegheny Mountain Dusky and Northern Dusky Salamanders have very similar biology, and because they occupy similar habitats and are separated by roughly four kilometres of river bank, the threats to their survival and recovery are virtually identical. Due to their extremely small range sizes in Ontario, both species are highly susceptible to habitat change. The current habitat is so limited that any degradation is likely to compromise the long-term survival of these salamanders in Ontario.

Disruption or Contamination of Groundwater

Allegheny Mountain Dusky and Northern Dusky Salamanders in Ontario utterly depend upon the groundwater discharge that feeds the streams and seeps in which they dwell. Any diminution, curtailment or interruption of the groundwater is a serious threat to the continuing existence of these salamanders. Lowering of groundwater and decreased dissolved oxygen concentrations have been linked to declines in other species of stream salamanders (Bowles and Arsuffi 1993, Turner 2004). Contamination of the surface water that maintains this hydrological system would likewise have potentially catastrophic effect upon the animals. Northern Dusky Salamander larvae have been shown to be sensitive to stream pollution and siltation, and densities are found to be inversely proportional to the degree of stream disturbance associated with urbanization (Petranka 1998). Population declines are generally attributed to siltation or loss of ground cover, although potential contaminants could include storm runoff from industrial and urban areas or herbicides and pesticides applied in the catchment areas of these streams. In addition, there is potential for groundwater feeding the seeps and streams to be redirected, decreased, or cut off as a result of large developments in the area and water flow should be monitored accordingly.

Erosion

Landslides or mudslides in the Niagara Gorge that in any way affect the salamanders' seep and stream-side habitats would be considered severe threats. At the top of the slope, uncontrolled stormwater flows from roadways, parking lots or other cleared areas have been discharged over the bank and have been known to trigger mudslides within the Gorge and erode trails (MNR staff D. Mills and A. R. Yagi, pers. comm. 2012).

Deforestation

Clearing of the forested canopy above the streams or seeps used by the salamanders would be a serious threat to these species by causing changes to the thermal regime and quality of subterranean refugia. Fortunately, the entire extent of significant habitat for these species is owned and managed by the Niagara Parks Commission (NPC), an important stakeholder in the overall recovery of these species. For that reason tree removal is unlikely, but remains a potential threat if it were to occur accidentally or through a natural event such as a mudslide. The newly discovered population of Allegheny Mountain Dusky Salamanders at Smeaton Creek occur on NPC land that is currently being leased to OPG. Communication between stakeholders regarding land use and potential impacts on salamanders and their habitat is therefore critical.

Habitat Degradation

Although salamanders are located in steep and normally inaccessible areas within the Niagara Gorge, the streams and seeps where these salamanders live are often explored by hikers who venture off the maintained trail (A. R. Yagi, pers. comm. 2012). This can stir up the stream bed, trample vegetation and increase erosion. Litter originating from the maintained trail may also contaminate the area.

Further, the invasive strain of the European Common Reed (*Phragmites australis*) has moved into the more gently sloping sections of the stream beds and is eliminating some potential habitat used by the salamanders wherever it is able to grow into thick stands. Research needs to be done to examine the potential impact of this plant on dusky salamanders and habitat, and what the most effective methods of removal may be.

Inbreeding

The genetic health of all three known populations of dusky salamanders in Ontario should be determined and monitored. As the Niagara River is considered a major barrier to dispersal for these salamanders, the Ontario populations are considered to be small population isolates that have no way of receiving gene flow from the nearest populations in New York State. Ontario Dusky Salamander populations are anticipated to be relatively small based on numbers detected to date and on the areas known to be occupied. Further, genetic studies across the northern range of Allegheny Mountain Dusky Salamanders have found that genetic variability is already very low, likely as a result of rapid population expansion since the last glacial cycle (Tilley and Mahoney 1996). As very small populations may be vulnerable to detrimental effects of inbreeding such as genetic defects and lower reproductive success (Hedrick and Kalinowski 2000), it would be prudent to determine whether inbreeding appears to be a problem, and if so

to consider introductions of individuals from New York to maintain the long-term health of the populations.

Population Loss

As the entire range of each species in Ontario is extremely limited, there is much concern that a single stochastic event (such as a landslide) could wipe out a whole population of either species at any given time. Further, groundwater levels and seepage outputs are susceptible to change as the result of human activity, especially near urban and industrial areas where these salamanders are found. A major spill of contaminants, which gets into the seepage surface water, would also likely be detrimental to these populations. For Northern Dusky Salamanders in particular, there may be little opportunity for dispersal to other suitable habitats. To safeguard against major losses to either of these species, measures should be taken to expand the known ranges of each species by locating new populations (if they exist) and creating or finding additional suitable habitat for introductions where appropriate.

Collection by People for the Pet Trade

While unlikely, there is some concern that salamanders could be taken from the Niagara Gorge and used in the pet trade. As populations are believed to be very low in numbers, removal of any numbers and of any age classes could have large impacts. Public education materials may help to convince park visitors of the special circumstances, and regulations, surrounding these populations, and the importance of leaving the habitat and populations intact.

1.7 Knowledge Gaps

The hydrology of the groundwater springs that feed the streams in which these salamanders live needs to be better understood. The extent of the groundwater recharge area is not fully known, and the results of a study investigating groundwater flows to the seeps and their relationship with surface water would be helpful. The salamanders are utterly dependent upon these sources of water, and the hydrology of the area needs to be thoroughly examined to ensure continued water quantity and quality. Aspects of water quality such as mineral content, pH, dissolved oxygen and contaminant load need to be ascertained so that changes that could affect the salamanders may be detected. While the extent of the groundwater recharge area, which contributes to the dusky streams, is not fully known, it likely includes the tableland area immediately west of the Niagara River Gorge and extending from the Niagara Escarpment south to the Whirlpool.

There is almost no demographic information on the populations of Allegheny Mountain Dusky Salamanders and Northern Dusky Salamanders in Ontario. Population sizes are not known, nor how much they fluctuate in size over time. Demographic characteristics such as mortality rates, growth rates and reproductive success are likewise unknown, as is information on dispersal potential and genetic diversity. This lack of information is in part because they have only recently been discovered and identified, and is also due

to the difficulty in safely accessing much of the habitat. However, considering the extremely limited extent of habitats they occupy, these salamanders are undoubtedly few in numbers and genetically impoverished. Since the significant threats to the welfare and recovery of these species are all related to habitat, gaps in the understanding of these species' population ecologies should not limit the ability to adequately define recovery goals, objectives, or approaches for these species, nor to recommend the habitats that should be considered for regulation.

1.8 Recovery Actions Completed or Underway

Following the discovery of populations of Allegheny Mountain Dusky and Northern Dusky Salamanders in Ontario, a provincial recovery team was established and identified the recovery goals detailed in this recovery strategy. The recovery team has produced educational and promotional materials on the salamanders, including stickers, magnets, shopping bags and a stewardship guide (Yagi et al. 2010). The Ontario Ministry of Natural Resources has completed some on-the-ground habitat enhancement work, particularly for the Allegheny Mountain Dusky Salamander population, including cedar planting, removal of European Common Reed and corridor planting.

Areas of significant habitat have been mapped and described in detail for the Queenston site (Yagi and Tervo 2008a) and for the Whirlpool site (Yagi and Tervo 2008b). However, the Smeaton Creek site has not yet been mapped to reflect areas of significant habitat. Work is underway in conjunction with OPG to trace the origins of the groundwater springs (W. F. Weller, pers. comm. 2012). Some protection is afforded to the salamander populations because the Niagara Parks Commission manages all of the territory occupied at these sites. Further, both the Allegheny Mountain Dusky Salamander and the Northern Dusky Salamander are provincially listed in Ontario as endangered under the *Endangered Species Act, 2007* (Ontario Regulation 230/08). In addition, the Allegheny Mountain Dusky Salamander is a federally endangered species listed on Schedule 1 of the Species at Risk Act (SARA). The Northern Dusky Salamander is not listed under SARA, although a COSEWIC status report update is in preparation.

2.0 RECOVERY

2.1 Recovery Goal

The recovery goal is to safeguard the existing known populations of Allegheny Mountain Dusky and Northern Dusky Salamander species, and if feasible, introduce each species to unoccupied habitat within the Niagara Gorge that is either created or found to be suitable with the aim of increasing known population sizes by 50 percent.

2.2 Protection and Recovery Objectives

Table 1. Protection and recovery objectives

No.	Protection or Recovery Objective
1	Protect and enhance existing significant habitat for Allegheny Mountain Dusky Salamanders and Northern Dusky Salamanders in Ontario.
2	Conduct a thorough population study, and if necessary maintain the genetic health of Allegheny Mountain Dusky Salamander and Northern Dusky Salamander populations in Ontario.
3	Locate additional populations, and expand the current ranges of Allegheny Mountain Dusky Salamanders and Northern Dusky Salamanders through introductions where appropriate.
4	Elicit public support and collaboration in the protection and recovery of Allegheny Mountain Dusky Salamanders and Northern Dusky Salamanders in Ontario.

2.3 Approaches to Recovery

Table 2. Approaches to recovery of the Allegheny Mountain Dusky and Northern Dusky Salamanders in Ontario

Relative Priority	Relative Timeframe	Recovery Theme	Approach to Recovery	Threats or Knowledge Gaps Addressed
1. Protect and enhance existing significant habitat for Allegheny Mountain Dusky Salamanders and Northern Dusky Salamanders in Ontario.				
Critical	Short-Term	Research – Potential Threats	1.1 Identify extent of groundwater recharge area.	<ul style="list-style-type: none"> • Disruption of groundwater • Poor understanding of hydrology and groundwater recharge area
Critical	Short-Term	Research – Potential Threats	1.2 Measure flows of seeps and streams occupied by dusky salamanders to determine seasonal and yearly averages.	<ul style="list-style-type: none"> • Disruption of groundwater • Poor understanding of hydrology and groundwater recharge area
Critical	Long-Term	Protection	1.3 Have source water protection (both surface and ground water) for land in the upgradient tableland areas.	<ul style="list-style-type: none"> • Disruption of groundwater • Poor understanding of hydrology and groundwater recharge area
Necessary	Long-term	Management	1.4 Ensure that all development activities on adjacent land that may involve contaminating or lowering of the groundwater table are monitored for groundwater impacts.	<ul style="list-style-type: none"> • Disruption or contamination of groundwater

Recovery Strategy for the Allegheny Mountain Dusky Salamander and the Northern Dusky Salamander in Ontario

Relative Priority	Relative Timeframe	Recovery Theme	Approach to Recovery	Threats or Knowledge Gaps Addressed
Necessary	Long-Term	Management and Monitoring	<p>1.5 Control quantity and quality of stormwater discharge from adjacent land including industrial, recreational and urban areas:</p> <ul style="list-style-type: none"> • eliminate the application of herbicides and pesticides in the vicinity of seeps; • monitor stormwater quality for pollutants; • develop an emergency spills action plan for the area; • create wetland areas to capture and slow down stormwater run-off; • plant native trees to stabilize the slope. 	<ul style="list-style-type: none"> • Disruption or contamination of groundwater • Erosion
Beneficial	Ongoing	Management and Monitoring	<p>1.6 Monitor erosion rates on the hillsides where salamanders are found for indications of slope instability.</p>	<ul style="list-style-type: none"> • Erosion
Beneficial	Ongoing	Management and Monitoring	<p>1.7 Ensure that forest canopy remains intact.</p>	<ul style="list-style-type: none"> • Deforestation
Beneficial	Ongoing	Research and Stewardship	<p>1.8 Discourage park visitors from off-trail hiking.</p>	<ul style="list-style-type: none"> • Habitat degradation
Beneficial	Ongoing	Research and Stewardship	<p>1.9 Investigate and implement best management practices for removal of European Common Reed.</p>	<ul style="list-style-type: none"> • Habitat degradation
<p>2. Conduct a thorough population study, and if necessary maintain the genetic health of Allegheny Mountain Dusky Salamander and Northern Dusky Salamander populations in Ontario.</p>				
Critical	Short-term	Research – Populations	<p>2.1 Conduct a thorough population study to determine more accurate population size and trends for each species in Ontario:</p> <ul style="list-style-type: none"> • may involve mark-recapture fieldwork and/or genetic analysis. 	<ul style="list-style-type: none"> • Inbreeding • Lack of demographic information
Necessary	Long-term	Monitoring and Assessment	<p>2.2 Monitor genetic health of populations:</p> <ul style="list-style-type: none"> • check for inbreeding with genetic analysis every 25 years. 	<ul style="list-style-type: none"> • Inbreeding

Recovery Strategy for the Allegheny Mountain Dusky Salamander and the Northern Dusky Salamander in Ontario

Relative Priority	Relative Timeframe	Recovery Theme	Approach to Recovery	Threats or Knowledge Gaps Addressed
Necessary	Short-term	Research and Management	2.3 If inbreeding appears to be a concern, look into the feasibility of salamander introductions from New York State, which is the nearest population source.	<ul style="list-style-type: none"> • Inbreeding
3. Locate additional populations, and expand the current ranges of Allegheny Mountain Dusky Salamanders and Northern Dusky Salamanders through introductions where appropriate.				
Critical	Short-term	Research and Management	3.1 Search suitable/accessible habitat in Niagara Gorge for any additional populations of dusky salamanders.	<ul style="list-style-type: none"> • Population Loss • Lack of demographic information
Necessary	Short-term	Research and Management	<p>3.2 Research the probability of success if individuals are translocated from sites outside of Ontario to suitable unoccupied habitats:</p> <ul style="list-style-type: none"> • determine likelihood of survival; • establish what numbers would be needed for a successful introduction and if they can be moved; • research other potential barriers to introductions; • identify areas with no obvious impediments to re-establishment; • investigate potential habitat along the Niagara Escarpment and Fonthill Kame Moraine. 	<ul style="list-style-type: none"> • Population Loss
Beneficial	Long-term	Management	3.3 If potential habitat is found (and successful introduction seems likely), pilot an introduction project.	<ul style="list-style-type: none"> • Population Loss

Recovery Strategy for the Allegheny Mountain Dusky Salamander and the Northern Dusky Salamander in Ontario

Relative Priority	Relative Timeframe	Recovery Theme	Approach to Recovery	Threats or Knowledge Gaps Addressed
4. Elicit public support and collaboration in the protection and recovery of Allegheny Mountain Dusky Salamanders and Northern Dusky Salamanders in Ontario.				
Beneficial	Ongoing	Education and Outreach	4.1 Prepare educational materials such as pamphlets to inform park visitors about the endangered status of these salamanders and the need to not disturb them or their habitat.	<ul style="list-style-type: none"> • Habitat degradation and salamander loss • Collection by people for pet trade

Narrative to Support Recovery Objectives and Approaches

The first objective for recovery is to protect, conserve and enhance the current habitats where Allegheny Mountain Dusky Salamanders and Northern Dusky Salamanders are found. Although habitat protection is already afforded through the Niagara Parks Commission, this does not guarantee that water feeding the streams and seeps inhabited by the salamanders will remain of high quality and quantity. For that reason the most critical approach to the recovery includes management of the supporting groundwater recharge and discharge areas to ensure that water quality and quantity are maintained. Monitoring and regulation of surface water is also needed to control potentially toxic discharges from industrial, recreational and urban areas in adjacent lands, as well as to mitigate high stormwater discharge that can lead to mudslides.

A second major objective for recovery is research to determine the actual size of each population in the Niagara Gorge and to better understand population trends for improved management. Maintaining the genetic health of the existing populations is also critical, as inbreeding depression can lead to reduced reproductive success.

The third objective is to locate new, potentially suitable habitat for the salamanders and determine the feasibility of expanding existing Ontario populations. Habitat along the Niagara Escarpment and the Fonthill Kame Moraine would have been connected to the Niagara Gorge in the past, and may offer potential habitat suitable for introductions. There is also some potential that additional populations of dusky salamanders may naturally occur at these locations. Suitable habitat may also be created in adjacent sites by adding cover objects, removing invasive plants and increasing moist areas where feasible. Because the known populations are so highly localized, a single catastrophic erosion event could wipe out an entire seepage area inhabited by these salamanders and thus extirpate the species in Ontario.

The fourth objective is public education and the engendering of good stewardship, which will be imperative for the long-term survival of these populations. The public needs to be aware that the Niagara Gorge is important habitat for these two species, and that activities such as off-trail hiking or collection of salamanders as pets may be detrimental to their continued survival. Consideration should be given to joining public education efforts toward dusky salamander conservation and protection with that of other wildlife species in the Niagara Gorge that share similar habitats and needs.

Supporting Narrative for Recovery Approaches 1.1 to 1.9:

One of the major priorities for the long-term recovery of these species is to ensure that groundwater quantity and quality is maintained. Current groundwater levels are adequate for the survival of Allegheny Mountain Dusky Salamanders and Northern Dusky Salamanders in the Niagara Gorge. However, any development on adjacent land that could change the hydrology, either increasing or decreasing peak flows and discharge volumes, increasing turbidity or sedimentation, or increasing water temperature, could spell disaster for dusky salamander populations and should be subject to assessment and monitoring. The extent of the groundwater recharge area is not fully known and needs to be thoroughly examined to ensure water quantity and

quality. Contaminated surface water could potentially infiltrate into the groundwater table within the Lockport formation. Alteration of water chemistry by the application of fertilizers or herbicides, increasing turbidity or dissolved solids and changing the temperature or pH could disrupt levels of dissolved oxygen and nutrients critical to the maintenance of salamander habitat. While the full extent of source waters remain unknown, it likely includes the tableland area immediately west of the Niagara River Gorge and from the Niagara Escarpment south to the Whirlpool.

Stormwater discharges from adjacent lands can also have catastrophic impacts on the salamander populations, both in the quality and quantity of water. Increases in erosion rates along the slope due to stormwater discharges may increase the instability of the slope. Resulting mudslides have the potential to decimate entire populations. While habitat stewardship activities have focused on replanting the mudslide areas in the short-term, wetland creation to capture and slow down the storm run-off discharges in the tablelands would be a long-term solution. Furthermore, contaminants such as herbicides, pesticides, oil, dangerous goods, and other pollutants can kill salamanders directly or make them more susceptible to disease by weakening their immune systems. As these salamanders are restricted to moist environments, and their larvae live within the seepages, groundwater pollution can have a catastrophic impact. Finally, an emergency spills action plan for this area would be valuable.

Deforestation is a threat to all forest-dwelling salamanders. However, it is not likely a serious threat for the Ontario populations of Allegheny Mountain Dusky Salamanders and Northern Dusky Salamanders which reside in lands that are owned and managed by the Niagara Parks Commission (Yagi and Tervo 2008a,b).

The invasive strain of the European Common Reed now grows in thick stands at the base of the slope in the Niagara Gorge. It acts to further stabilize the slope but also eliminates habitat use by dusky salamanders (Yagi and Tervo 2008a). Mechanical removal is necessary to control its spread; however, the long-term benefit of this approach has not yet been assessed. The removal of trees and shrubs in an area can lead to soil erosion, increased sedimentation in streams, changes in light intensity and temperature, changes in prey availability and modification or loss of habitat. This being the case, it is important to investigate and implement the best management practices for removal of European Common Reed.

Supporting Narrative for Recovery Approaches 2.1 to 2.3:

To better understand the management needs of these salamander populations, it is critical to determine current population sizes and trends for both species. Appropriate recovery actions may differ depending upon whether populations are increasing, decreasing or remaining constant.

Small populations are prone to inbreeding. This may become a concern with these populations over time, as natural migration across the Niagara River is virtually impossible, and dusky salamanders are not known to inhabit the opposite shore at this time. As inbreeding may result in decreased breeding success and other genetic

defects, it is recommended to check on the genetic health of Ontario dusky salamander populations at regular intervals. If found to be necessary, and introductions are deemed feasible, genetic rescue could be arranged. As genetically similar salamanders are known to inhabit adjacent New York State (Markle and Green 2005), there is potential that introduction of small numbers from New York into the Niagara Gorge populations could alleviate inbreeding effects.

Supporting Narrative for Recovery Approaches 3.1 to 3.3:

Stochastic events, such as major mudslides, could wipe out entire salamander populations within the Niagara Gorge. Therefore, it is critical to determine whether there is suitable habitat available for dusky salamander on adjacent land that will support introductions. Dispersal by salamanders out of the Niagara Gorge is presently unlikely as they are hemmed in by the Niagara Parkway at the top and the Niagara River on the bottom, yet it is possible that there were migration corridors between the Niagara Gorge and the Niagara Escarpment in the past. Suitable habitat may still exist along the Niagara Escarpment or the Fonthill Kame Moraine. If potential habitat is found, the feasibility of introductions should be considered.

If feasible and realistic within the habitat available, the recovery goal is to increase known populations of each species by 50%. As a new population was recently discovered, and potentially suitable (yet very difficult to access) salamander habitat remains to be surveyed, there is a good possibility that additional populations of both species may occur in the Niagara Gorge. Within the gorge there is plenty of suitable forest habitat; however, the limiting factor appears to be an abundance of quality seeps. Some habitat might be modified slightly to be more appealing to dusky salamanders, thereby encouraging additional populations where suitable. For instance, niche quality can be improved through adding cover objects (a potential limiting factor for abundance), along with the removal of invasive plant species where they are affecting natural groundcover or forest canopy. In addition, there may be some potential to increase available seep habitat and moist areas in the talus slope by re-routing the portion of groundwater not currently being used by salamanders to suitable but unoccupied areas. This goal is ambitious, and while work would need to be done to examine the feasibility of creating/modifying habitat and introducing species, it could be an important step in safeguarding the populations of these species in Ontario. Finally, improving the habitat between the two Allegheny Mountain Dusky Salamander populations could aid in dispersal and gene flow between the two sites.

Supporting Narrative for Recovery Approaches 4.1 and 4.2:

Although located in a steep and normally inaccessible area, streams and seeps in the Niagara Gorge are often explored by hikers who venture off the maintained trail. Litter from trail users is spread throughout the area. In addition, there may be potential for some salamanders to be collected by people for the pet trade. The human impact on these populations and how to mitigate this impact needs to be better understood, however, controlling human access to the habitats supporting dusky salamanders and educating trail users and visitors to the Niagara Gorge would likely help limit potential

damage. Discouraging human access off trail would not only be directly beneficial to the salamanders but could help to reduce erosion on the slopes as well.

2.4 Performance Measures

As dusky salamanders are nocturnal, elusive and liable to occupy habitat that is very difficult to access, obtaining reasonable estimates of population size for Ontario is difficult. It is likely that population estimates will require long-term and consistent monitoring including consecutive years of monthly surveys. Salamanders are expected to recover fairly quickly where optimal habitat is made available. Successful recovery will require both an increase in suitable habitat and an increase in abundance for both Allegheny Mountain Dusky and Northern Dusky Salamanders. As information is added through research and monitoring, it is recommended that recovery approaches be adjusted to ensure effectiveness.

Performance measures for each objective include:

Protect and enhance existing significant habitat for Allegheny Mountain Dusky Salamanders and Northern Dusky Salamanders in Ontario.

- Extent of the groundwater recharge area identified.
- Flows of seeps and streams occupied by salamanders measured to determine seasonal and yearly averages.
- Major projects or developments on the tablelands that could impact groundwater quantity or quality at salamander sites monitored.
- Emergency spills action plan developed.
- Program in place to annually monitor water quality and detect pollutants at salamander sites.
- Program in place to monitor erosion rates at base of Niagara River Shoreline.
- Invasive plants within/near salamander habitat removed as appropriate.

Conduct a thorough population study, and if necessary maintain the genetic health of Allegheny Mountain Dusky Salamander and Northern Dusky Salamander populations in Ontario.

- Population sizes, trends and demographics assessed for both species.
- Genetic health of each population quantified.
- Nearest source populations of each species identified in New York for potential introduction if inbreeding appears to be of concern.

Locate additional populations and expand the current ranges of Allegheny Mountain Dusky Salamanders and Northern Dusky Salamanders through introductions where appropriate.

- All other accessible suitable habitat within the Niagara Gorge and Niagara Escarpment surveyed for additional populations of dusky salamanders.
- Potential habitat for introductions within Niagara Gorge or Niagara Escarpment identified.

- Increased quality of adjacent suitable habitat so that populations of each species in Ontario have the potential to increase by a minimum of 50%.

Elicit public support and collaboration in the protection and recovery of Allegheny Mountain Dusky Salamanders and Northern Dusky Salamanders in Ontario.

- Education tools (pamphlets, magnets, etc.) developed and distributed to Niagara Gorge visitors to provide awareness of the impact of off-trail actions on salamander habitat.
- Outreach projects to encourage stewardship and involve stakeholders on adjacent lands above the Gorge initiated.

2.5 Area for Consideration in Developing a Habitat Regulation

Under the ESA, a recovery strategy must include a recommendation to the Minister of Natural Resources on the area that should be considered in developing a habitat regulation. A habitat regulation is a legal instrument that prescribes an area that will be protected as the habitat of the species. The recommendation provided below by the author will be one of many sources considered by the Minister when developing the habitat regulation for this species.

All populations of Allegheny Mountain Dusky and Northern Dusky Salamanders in the Niagara Gorge occupy forested areas with groundwater discharges. While their habitat requirements are virtually the same, Allegheny Mountain Dusky Salamanders are slightly more terrestrial and may inhabit semi-permanent streams or seeps, whereas Northern Dusky Salamanders are nearly always located in permanent streams or seeps. Preservation of these moist areas within a forested habitat is essential.

All three known populations of dusky salamanders in Ontario are completely dependent on the continuing existence of the seeps and streams emanating from rock layers on the sides of the Niagara Gorge. Any regulation concerning the areas presently occupied by the salamanders would become irrelevant if the springs and the ground water flow that feeds them were to become contaminated or disrupted. Thus the adjacent land above the Gorge that serves as the catchment basin for these springs should also be considered if the long-term survival of these salamander populations is to be ensured.

Allegheny Mountain Dusky Salamander

Direct Habitat

The two localities inhabited by Allegheny Mountain Dusky Salamanders are found on the west bank of the Niagara Gorge near Queenston. Each consists of a single, permanent groundwater discharge stream running down a very steep gradient through mixed deciduous forest (Yagi and Tervo 2008a, Weller 2010, 2011). The origin of both cascades is groundwater, which seeps out from rock layers at an elevation below the tableland. As all life stages of the Allegheny Mountain Dusky Salamander depend to

some extent on permanent streams or seeps and on rocky habitat, it is recommended that these stream areas be included in a habitat regulation.

Forested areas include the subterranean frost-free environment, soil, wet cavities along stream edges, vegetation, canopy cover, rocks, leaf litter and logs surrounding seep areas. This habitat provides shelter and food resources, and is critical to the survival and recovery of the species. Although the movements of Allegheny Mountain Dusky Salamanders in these populations are not well known, in other parts of its range individuals have been found up to 75 m from water (Organ 1961). For this reason, dispersal habitat for Ontario populations should include the forest floor extending to 75 m from the edges of a stream or associated seep occupied by these salamanders. Consequently, it is recommended that the entire extent of the two groundwater discharge streams and a 75 metre zone of forested land on both sides of each stream be included in the habitat regulation. Therefore, total direct habitat recommended for regulation of Allegheny Mountain Dusky Salamanders at the Queenston site is 1.98 ha, and for the Smeaton Creek population, 2.54 ha.

Finally, as two populations of Allegheny Mountain Dusky Salamanders (roughly half a kilometre apart) are now known in the Niagara Gorge, it is recommended that the area between the two localities be included in the habitat regulation as a dispersal corridor. While direct dispersal is not expected to occur frequently, it may be possible for salamanders to cross such distances over time in ideal cool/moist conditions. Gene flow between the sites would help to mitigate potential impacts of inbreeding that could occur in small isolated populations. The corridor habitat makes up an additional 4.2 ha of direct habitat, providing a total of 8.72 ha (the two sites plus the corridor) recommended for direct habitat regulation for the species.

Indirect Habitat

Populations of Allegheny Mountain Dusky Salamanders in the Niagara Gorge rely on the groundwater seepage streams during all life stages. Any decrease, curtailment or interruption of the ground water is likely to be detrimental to salamander recovery. Further, studies have demonstrated that siltation and urban impacts can decrease water quality and reduce dusky salamander populations. As a result, protection of groundwater quantity and quality needs to be considered in a habitat regulation for the long-term survival of this species in Ontario.

A study is in progress to determine the relationship between the water level in the Sir Adam Beck complex reservoir and stream flow at the Smeaton Creek site, Queenston site and Whirlpool site. The results of this study should be incorporated into follow-up documentation related to this recovery strategy. Although the full extent of the groundwater recharge area has yet to be determined with the appropriate hydrological studies, the Sir Adam Beck reservoir operates within the elevation of groundwater discharge areas and may play a role in maintaining a hydraulic gradient toward the seepage area of Allegheny Mountain Dusky Salamander populations. In late 2011, OPG lowered water in the reservoir to zero as part of an initiative to investigate future re-lining the reservoir to prevent leakage. During this time, it was observed that flow to

Smeaton Creek was dramatically reduced (A. R. Yagi, pers. comm. 2012). While a detailed analysis is needed to explicitly make the connection between the reservoir and stream or seepage flow, there is potential for the reservoir to be contributing a large amount of the flow to Smeaton Creek, and perhaps some to the Queenston Allegheny Mountain Dusky Salamander population as well.

It is therefore recommended that indirect habitat regulation include the groundwater recharge area and surface water catchment that feeds the source springs of both Allegheny Mountain Dusky Salamander populations. While detailed hydrological studies will provide a better sense of the extent of this area, a rough estimate includes some 700 ha of tableland and adjacent lands (Yagi and Tervo 2008a).

Northern Dusky Salamander

Direct Habitat

Although movements of Northern Dusky Salamanders in this population are not well understood, the average home range of individuals in USA populations is estimated to extend not further than 15 m from a stream or seep (Petranka 1998). Streams and seeps are critical habitat for larvae to develop and provide year-round essential moisture for adults. For this reason, it is recommended that all of the permanent or semi-permanent groundwater seeps within the currently occupied range of Northern Dusky Salamanders at the Whirlpool site be included in a habitat regulation.

Terrestrial forested habitat is important as a foraging area for adult salamanders. While under most conditions Northern Dusky Salamanders will remain near a permanent source of water, under ideal conditions (wet/cool nights) it is likely that they will disperse much further into the forest habitat to search for food or mates. Seepage areas occupied by Northern Dusky Salamanders at the Whirlpool site are quite dynamic in terms of flow, and can vary greatly from year to year depending on amounts of rainfall. Seasonality is also likely to influence seepage flow, although seasonal aspects of the Whirlpool seepage flows have not been determined. During periods of heavy rainfall seepage flow increases, saturating forest floor and increasing seepage areas. Such events can dramatically increase the available terrestrial habitat accessible to these salamanders. Because of the dynamic nature of the seeps at this site, a 75 m area extending from all permanent and semi-permanent seeps is proposed as a precautionary minimum for direct habitat protection. This will help to ensure that we capture all of the hydrologic function of this site and enable dispersal between the many seepage areas. Further, it provides enough habitat protection to allow for some changes to seepage flow over time. The total direct habitat recommended for regulation for the Northern Dusky Salamander is 3.36 ha.

Indirect Habitat

While we still do not fully understand the extent of the groundwater recharge area, it is evident that shallow groundwater seeping into the gorge is the predominant source of essential moisture for these salamander populations. Therefore it is highly recommended that some level of source water protection (both surface and groundwater) be provided for land in the up-gradient tableland areas. The groundwater

source is believed to originate in the Lockport rock formation. While the full extent of this area has not yet been determined (Yagi and Tervo 2008b), approximately 550 ha of tableland and adjacent lands are likely involved. This includes lands immediately west of the Niagara River Gorge and extending from the Niagara Escarpment to the Whirlpool. The maintenance of the groundwater discharge is essential to the long-term survival of all dusky salamander populations in Ontario. As a result, major projects on the tableland that have the potential to affect groundwater quality and quantity need to be thoroughly assessed and monitored once initiated.

Other considerations

The populations of both dusky salamander species in the Niagara Gorge are recent discoveries made as the result of intensive off-trail surveys in steep and treacherous terrain. It is quite possible that additional populations of both dusky salamanders may exist in the province. Areas of potential salamander habitat need to be searched extensively wherever possible and any new areas where dusky salamanders are found need to be quickly added to an area of habitat regulation. Further, where suitable habitats are available (or where available habitats can be made suitable), introductions should be considered and habitat regulation extended to include habitat at introduction sites.

GLOSSARY

Committee on the Status of Endangered Wildlife in Canada (COSEWIC): The committee responsible for assessing and classifying species at risk in Canada.

Committee on the Status of Species at Risk in Ontario (COSSARO): The committee established under section 3 of the *Endangered Species Act, 2007* that is responsible for assessing and classifying species at risk in Ontario.

Conservation status rank: A rank assigned to a species or ecological community that primarily conveys the degree of rarity of the species or community at the global (G), national (N) or subnational (S) level. These ranks, termed G-rank, N-rank and S-rank, are not legal designations. The conservation status of a species or ecosystem is designated by a number from 1 to 5, preceded by the letter G, N or S reflecting the appropriate geographic scale of the assessment. The numbers mean the following:

- 1 = critically imperilled
- 2 = imperilled
- 3 = vulnerable
- 4 = apparently secure
- 5 = secure

Costal grooves: A set of parallel, vertical grooves between the ribs on the sides of some salamanders, newts and their larvae.

Cross-section: A surface or shape that is or would be exposed by making a straight cut through something, especially at right angles to an axis.

Dorsal: Relating to the upper side or back of an animal.

Endangered Species Act, 2007 (ESA): The provincial legislation that provides protection to species at risk in Ontario.

First-order stream: A stream that has no permanent or semi-permanent tributaries feeding into it.

Hybridization: the act of mixing different species or varieties of animals or plants, thus producing hybrids.

Keeled: A flattened, ridge-like part.

Plethodontid: Lungless salamanders from the family Plethodontidae.

Refugia: An area in which organisms can survive through a period of unfavourable conditions.

Seep: Flow or leak slowly through porous material or small holes.

Species at Risk Act (SARA): The federal legislation that provides protection to species at risk in Canada. This act establishes Schedule 1 as the legal list of wildlife species at risk to which the SARA provisions apply. Schedules 2 and 3 contain lists of species that at the time the Act came into force needed to be reassessed. After species on Schedule 2 and 3 are reassessed and found to be at risk, they undergo the SARA listing process to be included in Schedule 1.

Species at Risk in Ontario (SARO) List: The regulation made under section 7 of the *Endangered Species Act, 2007* that provides the official status classification of species at risk in Ontario. This list was first published in 2004 as a policy and became a regulation in 2008.

Spermatophore: A cone-shaped jellylike mass topped with a sperm cap, deposited by male salamanders during courtship.

REFERENCES

- Alvo, R. and J. Bonin. 2003. Rapport sur la situation de la salamandre sombre des montagnes (*Desmognathus ochrophaeus*) au Québec. Société de la faune et des parcs du Québec.
- Ashton, R.E. Jr. 1975. A study of movement, home range, and winter behaviour of *Desmognathus fuscus* (Rafinesque). *Journal of Herpetology* 9:85-91.
- Bishop, S.C. 1941. The Salamanders of New York. *New York State Museum Bulletin* 324: 329-359.
- Bishop, S.C. 1943. *Handbook of Salamanders*. Comstock Publishing Company, Inc. Ithaca, New York. 535 pp.
- Bonin, J. 1999. COSEWIC Status Report on the Northern Dusky Salamander (*Desmognathus fuscus*) in Canada. Committee on the Status of Endangered Wildlife in Canada. Environment Canada, Ottawa.
- Boutin, A. 2006. Caractérisation de l'habitat d'une communauté de salamandres de ruisseaux comportant des hybrides. M.Sc. Thesis, Département de sciences biologiques, Université de Montréal. 91 pp.
- Bowles, D.E. and T.L. Arsuffi. 1993. Karst aquatic ecosystems of the Edwards Plateau region of central Texas, USA: A consideration of their importance, threats to their existence, and efforts for their conservation. *Aquatic Conservation: Marine and Freshwater Ecosystems* 3:317-329.
- Bruce, R.C. 1993. Sexual size dimorphism in Desmognathine salamanders. *Copeia* 1993:313-318.
- COSEWIC 2007. COSEWIC assessment and update status report on the Allegheny Mountain Dusky Salamander *Desmognathus ochrophaeus* (Great Lakes/St. Lawrence population and Carolinian population) in Canada. Committee on the Status of Endangered Wildlife in Canada. Ottawa. viii + 32 pp.
- Feder, M.E. 1983. Integrating the ecology and physiology of plethodontid salamanders. *Herpetologica* 39:291-310.
- Feder, M.E. and P.L. Londos. 1984. Hydric constraints upon foraging in a terrestrial salamander, *Desmognathus ochrophaeus* (Amphibia: Plethodontidae). *Oecologia* 64:413-418.
- Fitzpatrick, L.C. 1973. Energy allocation in the Allegheny Mountain Salamander *Desmognathus ochrophaeus*. *Ecological Monographs* 43:43-58.

- Forester, D.C. 1979. The adaptiveness of parental care in *Desmognathus ochrophaeus* (Urodela: Plethodontidae). *Copeia* 1979:332-341.
- Grover, M.C. 2000. Determinants of salamander distribution along moisture gradients. *Copeia* 2000:156-168.
- Grover, M.C. and H.M. Wilbur. 2002. Ecology of ecotones: Interactions between salamanders on a complex environmental gradient. *Ecology* 83:2112-2123.
- Hall, R.J. 1977. A population analysis of two species of streamside salamanders, genus *Desmognathus*. *Herpetologica* 33:109-113.
- Hedrick, P.W. and S.T. Kalinowski. 2000. Inbreeding Depression in Conservation Biology. *Annual Review of Ecology and Systematics* 31:139-162.
- Holomuzki, J.R. 1980. Synchronous foraging and dietary overlap of three plethodontid salamanders. *Herpetologica* 36:109-115.
- Hom, C.L. 1987. Reproductive ecology of female dusky salamanders, *Desmognathus fuscus* (Plethodontidae), in the southern Appalachians. *Copeia* 1987:768-777.
- Hom, C.L. 1988. Optimal reproductive allocation in female dusky salamanders : A quantitative test. *American Naturalist* 131:71-90.
- Houck, L.D., S.J. Arnold, and R.A. Thisted. 1985. A statistical study of mate choice: sexual selection in a Plethodontid salamander (*Desmognathus ochrophaeus*). *Evolution* 39:370-386.
- Jones, R.L. 1986. Reproductive Biology of *Desmognathus fuscus* and *Desmognathus santeetlah* in the Unicoi Mountains. *Herpetologica* 42:323-334.
- Kamstra, J. 1991. Rediscovery of the Northern Dusky Salamander, *Desmognathus fuscus*, in Ontario. *Canadian Field-Naturalist* 105:561-563.
- Keen, W.H. 1979. Feeding and activity patterns in the salamander *Desmognathus ochrophaeus* (Amphibia, Urodela, Plethodontidae). *Journal of Herpetology* 13:461-467.
- Keen, W.H. and L.P. Orr. 1980. Reproductive-cycle growth and maturation of northern female *Desmognathus ochrophaeus*. *Journal of Herpetology* 14:7-10.
- Krzysik, A.J. 1980. Microhabitat selection and brooding phenology of *Desmognathus fuscus fuscus* in western Pennsylvania. *Journal of Herpetology* 14:291-292.

- Markle, T.M. and D.M. Green. 2005. Molecular Identification of Allegheny Mountain Dusky Salamanders, *Desmognathus ochrophaeus*, in Southern Ontario. Report for the Ontario Ministry of Natural Resources (OMNR), Niagara, Ontario. 8 pp.
- Markle, T.M. and D.M. Green. 2006. Molecular comparison of Allegheny Mountain Dusky Salamanders, *Desmognathus ochrophaeus*, in Southern Ontario and New York State. Report for Ontario Ministry of Natural Resources (OMNR), Niagara, Ontario. 7 pp.
- Markle, T.M., D.M. Green, A. Yagi, and W.F. Weller. 2006. *Desmognathus ochrophaeus* (Allegheny Mountain Dusky Salamander) in Ontario. Herpetological Review 37(4):482-483.
- Means, D.B. 2005. *Desmognathus fuscus* (Green 1818) Northern Dusky Salamander. Pp. 708-710, In M. Lannoo (Ed.). Amphibian Declines: The Conservation Status of United States Species. University of California Press, Berkeley, CA.
- Montague, J.R. and J.W. Poinski. 1978. Note on the brooding behaviour in *Desmognathus fuscus fuscus* (Raf.) (Amphibia, Urodela, Plethodontidae) in Columbiana County, Ohio. Journal of Herpetology 12:104.
- Nash, C.W. 1908. Check list of the Batrachians and Reptiles of Ontario in Manual of Vertebrates of Ontario. Department of Education, Toronto. Warwick Bros. & Rutter, Limited, Printers, Toronto. 32 pp.
- Oldham, M.J. 2006. COSSARO Candidate Species at Risk Evaluation Form for Allegheny Mountain Dusky Salamander (*Desmognathus ochrophaeus*) prepared for the Committee on the Status of Species at Risk in Ontario (COSSARO), 11 pp.
- Organ, J.A. 1961. Studies of the local distribution, life history, and population dynamics of the salamander genus *Desmognathus* in Virginia. Ecological Monographs 31: 189-220.
- Orr, L.P. 1989. *Desmognathus ochrophaeus* (Cope), Mountain dusky salamander. pp. 181-189, in R. A. Pflingsten & F. L. Downs. Salamanders of Ohio. Bulletin of the Ohio Biological Survey 7(2). College of Biological Sciences, The Ohio State University. Columbus, Ohio.
- Pauly, T.K., and M.B. Watson. 2005. *Desmognathus ochrophaeus* Cope, 1859 Allegheny Mountain Dusky Salamander. Pp. 716-719, In M. Lannoo (Ed.). Amphibian Declines: The Conservation Status of United States Species. University of California Press, Berkeley, CA.
- Petranka, J.W. 1998. Salamanders of the United States and Canada. Smithsonian Institution Press, Washington.

- Petranka, J.W. and C.K. Smith. 2005. A functional analysis of streamside habitat use by southern Appalachian salamanders: Implications for riparian forest management. *Forest Ecology and Management* 210:443-454.
- Sharbel, T.F., J. Bonin, L.A. Lowcock, and D.M. Green. 1995. Partial genetic compatibility and unidirectional hybridization in syntopic populations of the salamanders *Desmognathus fuscus* and *D. ochrophaeus*. *Copeia* 1995:466-469.
- Spotila, J.R. 1972. Role of temperature and water in the ecology of lungless salamanders. *Ecological Monographs* 42:95-125.
- Tilley, S.G. 1969. Variation in the dorsal pattern of *Desmognathus ochrophaeus* at Mt. Mitchell, North Carolina, and elsewhere in the southern Appalachian Mountains. *Copeia* 1969:161-175.
- Tilley, S.G. 1970. Aspects of the reproductive and population ecology of *Desmognathus ochrophaeus* in the southern Appalachian Mountains. Ph.D. Thesis. University of Michigan, Ann Arbor, Michigan.
- Tilley, S.G. and M.J. Mahoney. 1996. Patterns of genetic differentiation in salamanders of the *Desmognathus ochrophaeus* complex (Amphibia: Plethodontidae). *Herpetological Monographs* 10:1-42.
- Tilley, S.G. 1997. Patterns of genetic differentiation in Appalachian *Desmognathine* salamanders. *Journal of Heredity* 88: 305-315.
- Turner, M.A. 2004. Some Water Quality Threats to the Barton Springs Salamander at Low Flows. Watershed Protection Development Review. Water Resource Evaluation Section, Environmental Resource Management Division. 11pp.
- Weller, W.F. 2010. Results of Field Investigations for Dusky Salamanders (*Desmognathus*) in Smeaton Creek, R.M. Niagara in 2010. Report prepared by Environment Division, Hydro Business, Ontario Power Generation for Niagara Plant Group, Hydro Business, Ontario Power Generation. December, 2010.
- Weller, W.F. 2011. Results of Field Investigations for Dusky Salamanders (*Desmognathus*) in Smeaton Creek, R.M. Niagara in 2011. Report prepared by Environment Division, Hydro Business, Ontario Power Generation for Niagara Plant Group, Hydro Business, Ontario Power Generation. December, 2011.
- Weller, W.F., pers. comm. 2012. *Email correspondence to T. Markle*. 2012. Sr. Environmental Scientist, Hydro Business Unit, Ontario Power Generation, Niagara-on-the-Lake, Ontario.

- Whiteman, H. H. and S. A. Wissinger. 1991. Differences in the antipredator behavior of three plethodontid salamanders to snake attack. *Journal of Herpetology* 25:352-355.
- Yagi A.R and R. Tervo. 2008a. Species at risk habitat mapping for the Allegheny Mountain Dusky Salamander (*Desmognathus ochrophaeus*) -- A test of draft habitat mapping guidelines. Ontario Ministry of Natural Resources 12 pp.
- Yagi A.R and R. Tervo. 2008b. Species at risk habitat mapping for the Northern Dusky Salamander (*Desmognathus fuscus*) -- A test of draft habitat mapping guidelines. Ontario Ministry of Natural Resources 12 pp.
- Yagi, A.R., T. Markle, A. Brant, and R. Tervo. 2010. Québec and Ontario Stream Salamander Stewardship Guide: A Resource and Field Guide for Living with Stream Salamanders. Prepared for Environment Canada, Habitat Stewardship Program. iii + 37 pp.
- Yagi, A.R., pers. comm. 2012. *Email correspondence to T. Markle*. February 2012. Management Biologist, Ontario Ministry of Natural Resources, Vineland Station, Ontario.

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